IEEE Access
Multidisciplinary | Rapid Review | Open Access Journal

Received March 1, 2018, accepted April 23, 2018, date of publication May 9, 2018, date of current version June 5, 2018.

Digital Object Identifier 10.1109/ACCESS.2018.2834391

Clinically Harmonized Wellness Concepts Model for Health and Wellness Services

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This work was supported in part by the Ministry of Science and ICT (MSIT), South Korea, under the Information Technology Research Center support program supervised by the Institute for Information and Communications Technology Promotion (IITP), under Grant IITP-2017-0-01629, in part by the IITP grant through the Korea government(MSIT) under Grant 2017-0-00655, and in part by the Korea Research Fellowship Program through the National Research Foundation of Korea (NRF) through the Ministry of Science and ICT under Grant NRF-2016H1D3A1938039.

ABSTRACT A considerable number of frameworks and platforms are available to model terminologies in the clinical domains, but wellness domain lacks a development framework. The objective of this paper is to develop a clinically influenced and harmonized wellness concepts model (WCM) in order to support diverse wellness applications and services. This model is supported by a novel framework in the wellness domain. In order to develop wellness concepts model, the proposed framework is divided into four processes; start-up and initiation process, WCM modeling and evolution process, WCM production process, and release process. The WCM modeling and evolution process extracts top level hierarchical concepts from the existing published literature using a systematic review process. The framework also extends its scope to evolution using the wellness recommendations guidelines. The evolution process is supported by clinical concepts harmonization with the help of terminology standard, SNOMED CT. We validated the top level hierarchical concepts using a group of experts based on a decision-making method known as the nominal group technique (NGT). In the final decision of the NGT, 14.7% of the hierarchical concepts are eliminated from the model due to their voting score of less than 70% in the expert panel. The top level concepts of the model are cross-validated using structured equation modeling (SEM). The chi-square (χ^2) test and root mean square error of approximation test results demonstrated the acceptable goodness of fit indices for the WCM with respect to experts' and users' opinions. In order to fill the gap that existed in wellness and clinical domain, this paper systematically investigated concepts for building a clinically harmonized model called the WCM. The proposed WCM development framework is validated through the NGT and SEM.

INDEX TERMS Wellness concepts model, wellness domain, interoperable and shareable knowledge, holistic wellness model, harmonization with SNOMED CT.

I. INTRODUCTION

A. MOTIVATION

In the current wellbeing paradigm, individuals focus on positive aspects of health and wellness to protect themselves from illness based on the illness-health-wellness continuum [1], as shown in Figure 1. Health and wellness are often used interchangeably but their origins and meanings are different [2]. Health is state of complete physical, mental, and social wellbeing, and it is the absence of disease, while wellness refers to the state of living an optimally healthy lifestyle and wellness is more than healthcare [2], [3]. Researchers in health and social sciences proceeded their research directions towards abnormality, disease, sickness, and dysfunction, opposite to wellness based on pathogenic paradigm [4]. Wellness has been deliberated as a model for counseling and development for a healthier life and has a long history of counseling [5], [6]. According to Chini and Dorner from the Austrian Medical Association [7], Austria will face additional

FIGURE 1. Illness-health-wellness continuum [1].

costs of 1.6 billion Euros in 2030, increasing to 3.7 billion Euros in 2050 [8], due to the high percentage of risky habits in youth. In Europe, about 60% of diseases are associated with the seven leading health risk factors, some of these are tobacco, alcohol, overweight, poor nutrition, and physical activity [9]. According to Branca *et al.* [10], 28-79% of adults are overweight in the World Health Organization (WHO) European Region and nearly 30% of adults are smokers [11].

In current epoch of internet of things (IoT), a variety of healthcare and wellness applications are performing the role of counselor and recommender to change risky behaviors to healthy ones. The recommendation systems combine different healthcare and wellness knowledge with individuals data to provide personalized reminders, prompts, alerts, and guidance [12]. In knowledge-based recommendation systems, the shareability and integration of a knowledge base with many heterogeneous databases models is a challenging task [13]. In the clinical domain, knowledge shareability and interoperability can be achieved using standard terminologies (i.e., SNOMED CT, LOINC, and ICD10) and standard data models [14]. Unlike clinical domain, the wellness domain lacks such standard terminologies and data models. Therefore, knowledge integration and sharing are considerable barriers to the adoption of recommendation systems in the wellness domain. A holistic wellness concepts model (WCM) is needed to overcome the limitations of standard terminologies required for knowledge-related core functions such as knowledge acquisition, integration, and reusability.

Moreover, the clinical terminology development processes (i.e. SNOMED CT, ICD-10, and LOINC) focus on the domain experts' knowledge and their validation only, because of the domain's sensitive nature [15]. The WCM development process amalgamates the domain experts' knowledge with concepts extraction from published articles and guidelines in the evolution process. This process validates the model through experts opinion and statistical method.

B. WCM IMPORTANCE IN KNOWLEDGE-BASED SYSTEMS AND SERVICES

The WCM plays a vital role in the creation of a reusable and integrable knowledge base. Usually, the recommendation systems generate recommendations based on users' lifelog information. Whenever the schema and data of the lifelog repository for the different systems are heterogeneous, diverse, and do not follow standard terminologies, the integration of the systems with a knowledge base becomes challenging and is considered a critical issue in the adaption of decision and recommendation systems [16]. A unified concepts model and the representation of knowledge overcome the limitation of reusable and integrable knowledge base [17]. Therefore, a well-originated and holistic WCM can play a pivotal role in the initial breakthrough for the standard and unified concepts model in the wellness domain. This will result in reusability and easy integration of a knowledge base with heterogeneous legacy systems.

C. SYNERGY OF WELLNESS WITH CLINICAL MODELING

Wellness terminologies have the same synergy as clinical terminologies with respect to utilization, such as the concepts usage in clinical and wellness notes, protocols, content, and knowledge of decision support and recommendation systems. For instance, the wellness applications used heterogeneous knowledge bases using diverse wellness concepts with the same synergy of clinical decision support systems (CDSS) [18]–[20].

In the clinical domain, there exist standard terminologies such as the International Classification of Diseases (ICD-9-CM), ICD-10 [21], [22], SNOMED CT [23], Read Codes Version 2, 3 [24], the Unified Medical Language System (UMLS) [25], Current Procedural Terminology (CPT) [48], and NANDA [49]. SNOMED CT is a comprehensive buildup of SNOMED RT and Clinical Terms Version 3 [45]. In numerous studies, it has been observed that SNOMED CT provides a large amount of coverage of clinical content in various domains such as diagnosis, treatment, laboratory tests, clinical statements, problems, and nursing. For instance, SNOMED CT covered 92.5% of the international classification for nursing practice (ICNP) nursing diagnosis and intervention catalogue concepts [26]. Similarly, SNOMED CT provided greater coverage of about 98.5% for the diagnosis and medical problems entered into a computerized physician order entry (CPOE) system [27]. Therefore, we considered SNOMED CT as a baseline for our proposed WCM and partially followed its design, development, and harmonization strategies and processes.

D. PROPOSED SOLUTION OVERVIEW: WELLNESS CONCEPTS MODEL (WCM)

We designed a WCM development framework to develop, evolve, and validate the WCM. It includes *start-up and initiation process*, *WCM modeling and evolution process*, *WCM production process*, and a *release process*. In this study, we focus on the contributing process of *WCM modeling and evolution*, which consists following activities;

- Model Creation: The top level hierarchical concepts model of the WCM is designed using extensive literature with a systematic review process.
- Model Evolution: The evolution process evolves the WCM using the wellness concepts used in published guidelines.
- Harmonization with standard terminology: We performed the harmonization activity to utilize the existing standard concepts, codes, and descriptions in the WCM.
- WCM Validation: We validated the top level concepts of the WCM using the NGT process and cross-validated

them using the statistical methods of structured equation modeling (SEM).

II. RELATED WORKS

Based on an extensive survey, Roscoe [28] stated in 2009 that researchers have failed to agree on a definition and the dimensional structure of wellness. Although several authors have proposed different definitions of wellness, a unified definition of wellness has not been crafted [28]–[31]. Authors mostly agree that wellness is a multidimensional and synergistic construct that is represented as a continuum and it has no end state [28], [29], [32]. Most of the authors have also come to an agreement and assume that wellness is more than the absence of illness [28].

According to the WHO definition of wellness, it is a state of complete physical, mental, and social well-being, and not merely the absence of disease or infirmity [28]. Many researchers have proposed different wellness models; one of the popular wellness models is *Wheel of Wellness*, introduced in the 1990s by Sweeney and Witmer [33], [34]. According to this model, the life forces that affect an individual's life are family, religion, education/industry, media, government, and community.

In 2004, Myers and Sweeny [35] realized that the structure of the *Wheel of Wellness* should be re-examined due to the hypothesized relationships among its components and its complex structure. The *Indivisible Self* model was proposed as a higher-order wellness factor, which is based on Adler's [36] theory of holism, the indivisibility of self. Five main concepts are considered as second-order factors: *Essential Self, Social Self, Creative Self, Physical Self,* and *Coping Self* [35].

Depken [37] described wellness as mainly comprising five dimensions: *physical, intellectual, social, emotional*, and *spiritual*. Authors mostly agree with these five dimensions; however, Hettler [32] mentioned an extended model with a sixth dimension: *occupational*. In 1997, Adams *et al.* [38] excluded the *occupational* dimension and included *psychological* in the wellness model. In the current years of IoT, wellness concepts have been used in many service applications worldwide. The most targeted components of wellness in service applications are *physical, emotional, occupational, social*, and *psychological*.

One of the wellness ontologies, international classification of wellness (IWC) [39], has published by National Center for Biomedical Ontology (NCBO) on their BioPortal [40]. The wellness taxonomy of IWC comprises the emotional wellness, environmental wellness, financial wellness, intellectual wellness physical wellness, social wellness, spiritual wellness, vocational wellness, and wellness-NOS. Therefore, we included the IWC study in our survey with all mentioned concepts, but we used occupation and economic instead of vocational and finance of IWC, respectively, due to their use in many other studies [32], [41]–[44].

Miller [42] provided a very intensive study on the wellness history and development of the concepts model. The authors included important wellness factors such as physical, social, intellectual, demographics, mental, spiritual, emotional, occupation, and self-wroth in their proposed wellness model. Similarly, many research groups have designed and developed wellness models with distinct and overlapping concepts with each other. We included most of the wellness studies in our model creation using systematic review process. Therefore, our proposed model inspired by the amalgamation of all wellness models, discussed in the included studies, to produce a comprehensive wellness model.

There are many knowledge elicitation methods have used to acquire concepts, knowledge, and requirements in literature. For instance, CommonKAD [45] is well-known a comprehensive methodology for KBS development, which pay attention to the expertise modeling in different phases of development life cycle of KBS and focus on different managerial aspects of KBS. Similarly, expert knowledge elicitation have used to estimate the parameters in health economic decision model [46]. All these methodologies have focused on some specific elicitation approach based on their requirements and experimental environment. Although these approaches lack the evolution from guidelines, harmonization with clinical standards, and cross-validation using empirical and statistical methods.

III. METHODS AND MATERIALS

In this research, we emphasize the design, development, and evolution process of the concepts model in the wellness domain. It produces two artifacts in the form of a WCM development framework and the WCM terminology. In information technology research, real problems must be identified and conceptualized, appropriate techniques must be found for the solution, and these must be implemented and evaluated using appropriate methods and criteria [47]. Therefore, we followed a well-known and concise guidelines of DSR [48] and its checklist [49], which provides a problem-solving paradigm to help develop artifacts and applications for actual business needs and problems [48]. We have designed a WCM development framework to develop the WCM, which comprises of *start-up and initiation process*, *WCM modeling and evolution process*, *WCM production process*, and the *release process*, as shown in Figure 2.

In *Start-up and initiation process* of the WCM development, we performed the management tasks. a) We define the domain and scope of the wellness model such as physical, nutritional, environmental, clinical, and social aspects. b) We define the purpose and usage of wellness model such as wellness applications for physical activities, nutrition, and clinical recommendations and counseling systems. c) The team management activity is performed to manage domain personnel based on the domain's scope, purpose, and usage. d) After team organization, appropriate and scoped tasks are assigned to corresponding individuals with reasonable deadlines. e) In concepts source selection activity, credible resources are selected for developing a terminology model.

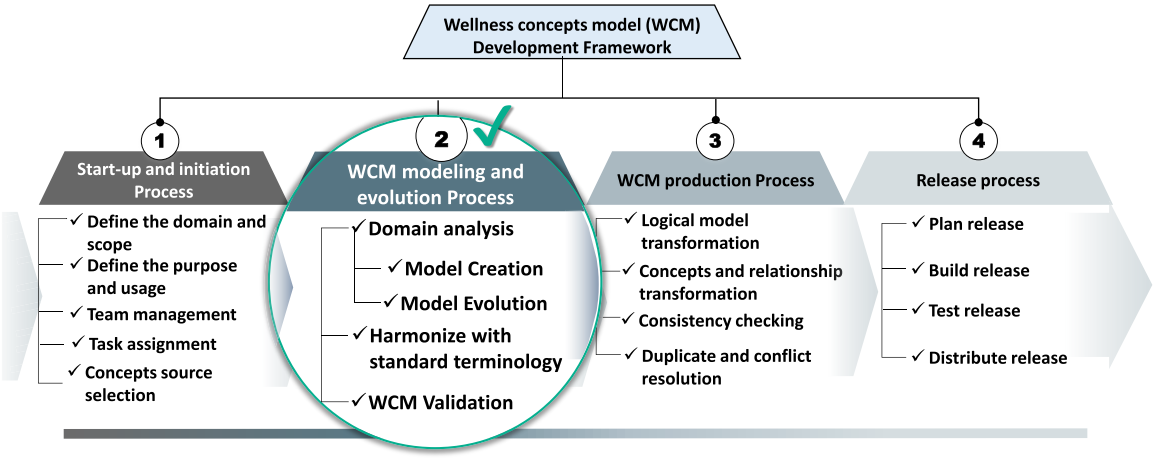

FIGURE 2. Wellness concepts model (WCM) development framework.

We selected distinguished published research papers for the design and development of the WCM, while online published guidelines were selected as a source for the evolution of the model.

The second *WCM modeling and evolution process* is an important and highly represents our contributions. Therefore, we focused on this process with more detail in following sub sections. This process comprises of *domain analysis* for the conceptual model creation and evolution, *harmonization with standard terminology*, and *WCM validation*.

In *WCM Production Process*, we transformed the conceptual model into an executable representation format. We selected an ontological representation for the WCM because it is a semantically rich representation of the knowledge [50]. Web Ontology Language (OWL) is used as a semantic web language to represent WCM ontology. The *WCM Production Process* has following sub-activities.

- In *logical model transformation* activity, the knowledge engineers and developers transform the conceptual model (harmonized and non-harmonized concepts) into a logical model representation, which is closer to the implementation.
- In *concepts and relationships transformation* activity, all the identified concepts and relationships are transformed to the desired executable representation.
- In *consistency checking* activity, we checked the syntactic and semantic consistency using Pellet [51] reasoner. WCM Ontology is validated using OntoClean framework [52]. The metaproperties such as essence, rigidity, identity, unity, and dependency of OntoClean framework are applied to evaluate the ontology.
- In *duplicate and conflict resolution* activity, the knowledge engineers removed anomalies such as duplicate and conflicting concepts, which are identified in previous activity.

In *Release process*, we followed the steps to release and distribute the WCM to the end users. In *plan release* step, we decided the release version, included/excluded changes, the source of the release, the target community, the date and time, and the configuration of the release. In *build release* activity, the actual build is prepared from the source code of the WCM. After successful build, we tested the build and fixed the runtime errors and bugs. Finally, in *distribute release* activity, the release is distributed by the selected source. The recommended sources for WCM distribution are the Linked Open Data (LOD) using "Linked Data Principles" [53] and any community-accessible browser.

A. WCM MODELING AND EVOLUTION PROCESS

1) DOMAIN ANALYSIS

The domain analysis required extensive literature to find wellness concepts and relationships in order to build the top-level of the hierarchies. The identified hierarchies should be capable of arranging the subtypes of concepts under the top-level concepts. The whole process is iterative; therefore we focused on wellness domain models and patterns, which have already been published in the literature, to initialize the conceptual model. In the evolution through subsequent iterations, different recommendation guidelines are used to extract concepts and their relationships, arranged under the initialized hierarchies of the conceptual model. Therefore, we performed modeling and evolution in two sub-activities: *model creation* and *model evolution*. In *model creation*, we modeled the top-level hierarchical concepts based on an extensive survey of wellness literature. In *model evolution*, we evolved the model by correlating concepts, used in recommendation guidelines, with top-level hierarchical concepts.

a: MODEL CREATION

We performed the domain analysis literature based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) process followed in [54] with few changes, such as keywords, article types, and search engines.

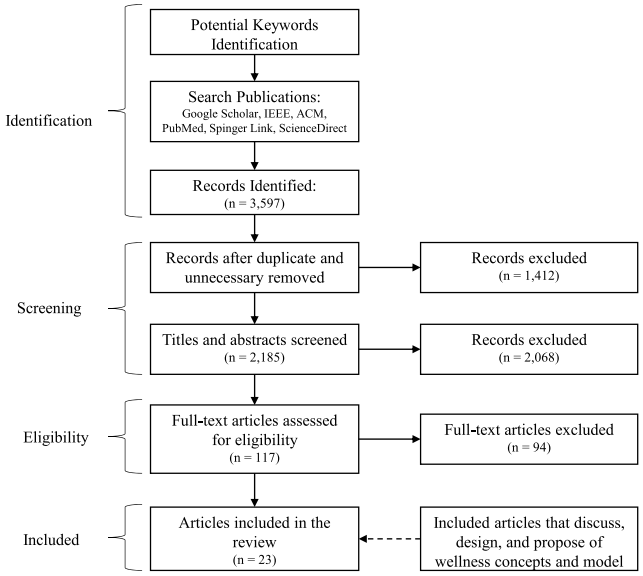

FIGURE 3. Systematic review process for survey literature.

We searched for the potential keywords of wellness, well-being, wellness model, holistic wellness model, and healthcare and wellness in the range of the year 1920 to 2016. We searched these terms in Google Scholar, IEEE Xplore Digital Library, Machinery (ACM), PubMed, SpringerLink, and ScienceDirect with backward and forward citations. After removal of duplicate, unnecessary, unrelated titles, and abstracts in screening phase, we downloaded 117 different publications related to wellness models. We analyzed all the downloaded publications and identified 23 of the publications that discuss, design, and propose wellness concepts or models. Including the report characteristics of eligibility criteria, we considered four points in articles, a) discussed wellness concepts individually, b) designed or proposed new wellness model, c) evolved or modified the existing wellness model, and d) introduced or discussed the semantics of wellness concepts. The systematic review process followed is depicted in Figure 3. We analyzed the selected publications extensively to find candidate wellness concepts. We compared and summarized different wellness concepts and models from the selected publications, described in Table 1. In the selected publications, different authors have used diverse concepts for the same meaning but we categorized those diverse concepts under the common title of concept. The resultant wellness concepts, mentioned in Table 1, were documented and visualized using a mind map. The mind map was selected because of its low level of difficulty, open extensibility, and medium to high memorability [55]. Additionally, most of the people are familiar and feel comfortable with the mind map technique using a simplified entity-relationship model (ERM) notation. The top level concepts of the WCM were provided to a domain expert panel for validation. The validation process will be discussed in Section III-A3.

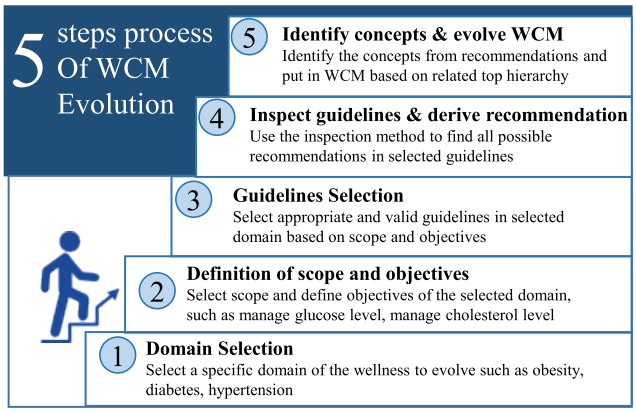

FIGURE 4. Five-step process of WCM evolution.

b: MODEL EVOLUTION

The WCM is evolved by finding the correlations between the concepts, which are extracted from related recommendation guidelines using an inspection method. The WCM evolution process consists of five steps as depicted in Figure 4. In the first step, a specific domain is selected based on the wellness requirements and field of interest. The wellness model cover different areas of healthcare and wellbeing such as obesity, diabetes, hypertension, mental disorders, dyslipidemia, and metabolic syndrome. In the second step, we defined the scope and objectives of the selected domain to evolve the WCM concepts in that particular domain. For instance, managing glucose and cholesterol levels, and handling cholesterol with other comorbidities are some of the important objectives and scopes for dealing with and managing diabetic patients.

In the third step, appropriate guidelines are selected based on the objectives and scope of the selected domain. Many healthcare and wellness institutions have designed and published recommendation guidelines to prevent unhealthy behaviors and to manage a healthier lifestyle.

In the fourth step, we identified the sections of the guidelines that describe recommendations pertaining to the selected objectives of the domain using an inspection method. In step five, the wellness concepts are identified from the recommendation text and represented in a conceptual graph [65]. After the wellness concepts are identified, concepts are searched in the current WCM to find duplicate concepts. The duplicate concepts are removed for placement in the WCM, while other identified concepts are connected to already existing concepts based on some appropriate relationship. The evolution process is explained in the following example scenario with each step of model evolution.

Example Scenario:

- *Step 1:* We selected diabetes domain to evolve the WCM for this scenario example.
- *Step 2:* We selected the scope to manage the glucose and cholesterol levels of patients; we considered cholesterol with other comorbidities to be beyond the scope of this scenario.

TABLE 1. Concepts identified in literature.

Wellness Concepts		Study References
Physical	Exercise	[56], [57], [57], [32], [41], [35], [42], [58], [1], [38], [59], [60], [61], [62], [37], [63], [64], [44], [40]
	Nutrition	[56], [57], [57], [32], [41], [35], [42], [58], [1] [38], [59], [60], [61], [62], [37], [63], [64], [44], [40]
	Prevention	[38], [44], [40]
Social	Family	[32], [41], [35], [42], [58], [1], [38], [43], [59], [60], [61], [62], [37], [63], [64], [44], [40]
	Love	[32], [41], [35], [42], [58], [1], [38], [43], [59], [60], [61], [62], [37], [63], [64], [44], [40]
	Community	[32], [41], [35], [42], [58], [1], [38], [43], [59], [60], [61], [62], [37], [63], [64] [44], [40]
	Friendship	[32], [41], [35], [42], [58], [1], [38], [43], [59], [60], [61], [62], [37], [63], [64] [44], [40]
Intellectual	Problem Solving	[32], [41], [42], [1], [38], [59], [60], [61], [62], [37], [63], [64], [44], [40]
	Creativity	[32], [41], [42], [1], [38], [59], [60], [61], [62], [37], [63], [64] [44], [40]
Demographics	Gender Identity	[41], [35], [42], [44]
	Cultural Identity	[41], [35], [42], [43], [44]
Sense	Sense of Worth	[57], [41], [35]
	Sense of Control	[57], [41], [35]
	Sense of Humor	[57], [41], [35], [1]
Mental/Stress Management		[56], [57], [41], [35], [42], [58], [1], [43], [44]
Spiritual		[56], [57], [32], [41], [35], [42], [1], [38], [43], [59], [60], [61], [62], [37], [63], [40]
Emotional		[57], [57], [32], [41], [35], [42], [1], [38], [43], [59], [60], [61], [62], [37], [63], [44], [40]
Occupation		[32], [41], [42], [61], [62], [44], [40]
Self-care		[41], [35], [1], [43], [44]
Leisure		[41], [35], [1], [44]
Education		[41], [58], [43], [44]
Thinking		[57], [35], [44]
Self-worth		[35], [42], [44]
Media		[41], [44]
Government		[41], [44]
Local Safety		[1], [44]
Institutional Concern		[1],
Personal Attribution		[1],
Physiological		[38], [44]
Political		[43],
Economic		[43], [44], [40]
Healthcare		[58], [43], [44]
Environment		[58], [63], [44], [40]
Liberty		[57]

- *Step 3:* We selected recommendation guidelines for diabetes management along with related physical activities and nutrition guidelines because diabetes is greatly affected by healthier activities and diet. The title of selected guideline is *"Standards of medical care in diabetes - 2016"* [66].
- *Step 4:* The domain experts inspected the guideline, identified the recommendation parts, and derived the recommendation. For instance, one of the recommendations has to do with the assessment test of the risk factor for diabetes, shown in Table 2.
- *Step 5:* After recommendation extraction, we extracted the concepts, identified the relationships among extracted concepts and built a conceptual graph as depicted in Figure 5, which is a formal representation of the aforementioned recommendation. The rectangles represent the concepts and circles represent the relationship between concepts based on semantics in the recommendation. The conceptual graph is used to evolve the WCM. Each concept of the conceptual graph is searched in the existing hierarchies of the WCM to avoid duplication. When the concept already exists, it is skipped, in other case the relationship of the concept is analyzed with concepts of WCM and added as a new concept.

TABLE 2. Recommendation extracted from guideline.

Recommendation: Categories of increased risk for diabetes
"Testing to assess risk for future diabetes in asymptomatic people should be considered in adults of any age who ar overweight or obese (BMI $\geq$ 25 kg/m^2 or $\geq$ 23 kg/m^2 in Asian Americans) and who have one or more additional risk factors for diabetes [66]."

The *"Is-A"* relationship in the conceptual graph shows the generalization of the concept and that concept can be directly

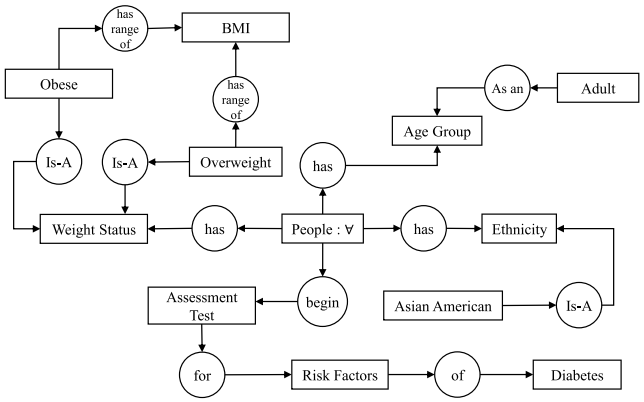

FIGURE 5. Conceptual graph created from recommendation.

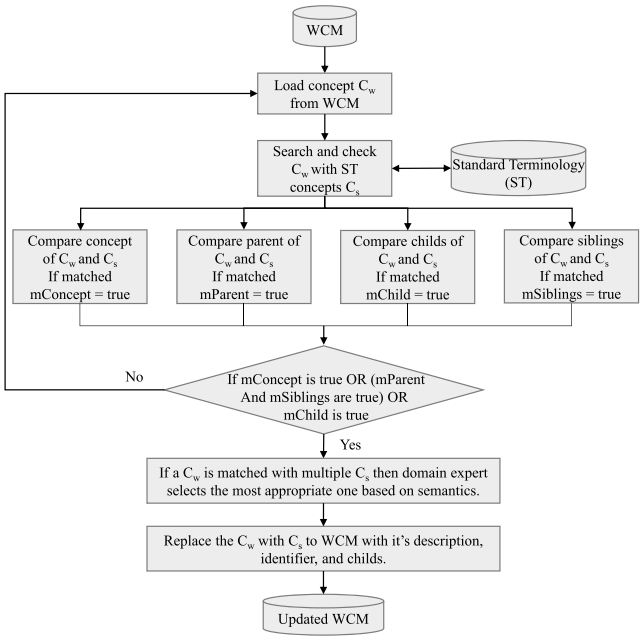

FIGURE 6. Working flow of harmonization process.

linked to its parents in the WCM. For instance, the concepts *Overweight* and *Obese* have an *"Is-A"* relationship with the concept *Weight Status*. Therefore, these two concepts are linked to the concept *Body Weight* in the WCM using an *"Is-A"* relationship, which already exists under the *Physiological* hierarchy, as shown in Figure 10. Similarly, relationships such as "*has*", *"of"*, and *"for"* show that the source and destination concepts belong to different hierarchies in the WCM. For example, there is an *"of"* relationship between *Risk Factor* and *Diabetes*. Therefore, *Risk Factor* is linked to the concept *Habits-Behavior* under the *Self-care* hierarchy while *Diabetes* is linked to the *Disease* under the *Healthcare* hierarchy of the WCM, as shown in Figure 10. The concept representation usually goes from generalization to specialization for each terminology. Therefore, the conceptual graph represents the concepts in the form of both specialization and generalization, and those concepts are easily integrateable in terminologies. Similarly, the conceptual graph helps with analyzing the relationships among concepts during the evolution process.

2) HARMONIZE WITH STANDARD TERMINOLOGY

In order to make the WCM an align and compatible model, we performed a harmonization process with a clinical standard terminology system. In this activity, a standard terminology is searched for concepts and aligned WCM with standard concepts. Therefore, the harmonization process also helps in the evolution of WCM by adding the child hierarchies. The process of harmonization is depicted in Figure 6.

In this process, each concept C_W of the WCM is compared with concepts C_S of standard terminology (ST). The concept is considered to be harmonized when the concepts or their children or their parents and siblings are matched. When a concept matched with multiple standard concepts then domain experts select the most appropriate one based on semantics. The description, code identifier and immediate children of the standard concept are placed in the WCM as a harmonized concept. The domain experts' intervention is necessary to select the immediate children of the standard concept during the addition process. When the immediate children are important in the wellness domain, then they are added to the WCM, otherwise, the children are ignored.

TABLE 3. Examples of harmonized concepts.

Harmonized Concepts	Standard Concepts	Code	Childs With [Codes]
Weight	Body weight	27113001	Birth weight [364589006] Body weight with shoes [424927000] Body weight without shoes [425024002] Dry body weight [445541000]
Obese	Obese	414915002	Body mass index 30+ - obesity [162864005] Body mass index 40+ - severely obese [408512008] On examination - obese [162690006]
Body Mass Index-BMI	Body mass index	60621009	Experts Decision: No need to add childs

In this study, SNOMED CT is used as the standard terminology for harmonization. According to the aforementioned recommendation, the concept *"Weight Status"* is matched with standard concepts "*Weights (code: 272102008, qualifier value), Body weight (code: 27113001, observable entity)*". According to the experts' decision, *"Weight Status"* is harmonized with *"Body weight (code: 27113001, observable entity)"* based on semantics types. Therefore, the *"Weight"* is replaced with *"Body weight (code: 27113001)"* and its children are added to the WCM. Table 3 shows some harmonized concepts, which are replaced in the WCM.

3) WCM VALIDATION PROCESS

a: VALIDATION PROCESS - EXPERT OPINION

In order to validate the top-level concepts of the WCM, we follow a formal expert group-based selection method, known as the *nominal group technique* (NGT) [67]. The NGT is selected because of its effectiveness in a multi-option decision-making process. A team of domain experts participated in a closed discussion to select appropriate concepts for the WCM. The following steps have been performed in the NGT method.

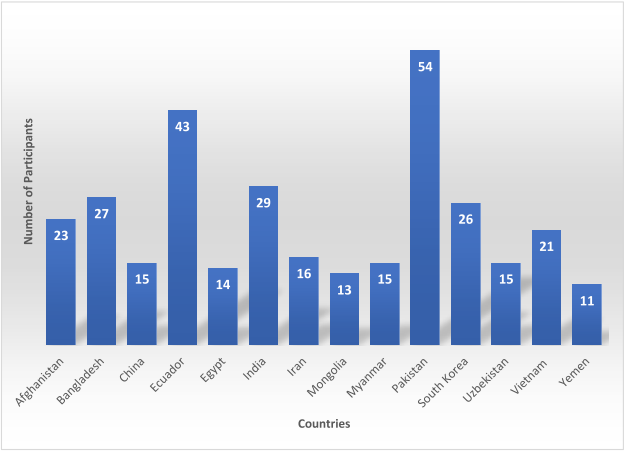

FIGURE 7. Number of participants with respect to countries.

- Introduced the team members and selected a leader to handle the meeting cordially. In the panel, three physical instructors (PI-1, PI-2, and PI-3), three nutritionists (N-1, N-2, and N-3), and three clinicians (C-1, C-2, and C-3) are participated.
- The WCM model concepts are provided to the domain experts and the purpose and voting process are discussed.
- All domain experts analyzed the individual top-level concepts of the WCM silently without any discussion.
- At the end of the designated time period, the domain experts are requested to rank the concept by voting according to the defined ranking criteria. The range of the voting criteria was from 1 to 5. The domain experts voted for a concept and updated the evaluation matrix accordingly.
- With the consensus of the domain experts, a threshold value was defined for removing the lower ranked concepts from the WCM.
- The voting ranks of each concept, given by experts, are aggregated to find the total vote of that particular concept.
- The concepts with a lower accumulative rank than the threshold value are removed.
- The resultant model is considered to be a validated WCM.

b: VALIDATION PROCESS - USER OPINION

In addition to expert opinion, we include user opinion for cross-checking of the WCM. We follow a well-known statistical method of structured equation modeling (SEM). SEM inspects the plausibility of complex models in terms of its significant constructs that domain experts and researchers have formulated for verification [1]. In this study, the population consisted of 322 including 146 graduate students, 94 researchers, and 82 employees from different organizations of fourteen different countries, as depicted in Figure 7. The participants are ensured with wellness field's job, research, and organization with experience of using any two wellness applications. The participants were aged between 24 and 59 years old.

We designed a questionnaire to measure and assess the top-level concepts of the WCM. We performed a statistical analysis to examine factors' structures using the SPSS Windows program [68]. We calculated the descriptive statistics to describe characteristics of the WCM concepts and to compare the results of experts' opinion and users' opinion.

We performed two important SEM tests, chi-square χ^2 and root mean square error of approximation (RMSEA), to cross-validate the NGT results and to find the goodness of fit of the model. The performed chi-square test observes the association between assumed and observed data, and it evaluates the assumed model against the observed data. Equation 1 calculates χ^2 using the input data in Table 7.

$$\chi^2 = \sum_{i=1}^{n} \frac{(O_i - E_i)^2}{E_i} \tag{1}$$

Where O_i represents the observed data, while E_i represents the expected value. In our study, the NGT processed data is assumed while the users' opinions are observed data. The null hypothesis H_0 is that the users' opinions about the WCM model are close to the domain experts' opinions. Therefore, we performed RMSEA test to find the goodness of fit model based on the null hypothesis. Based on the expected and assumed values in χ^2, we used Equation 2 to check goodness of file of users' opinion with experts' opinion.

$$RMSEA = \sqrt{max([((\chi^2/df) - 1)/(N - 1)], 0)} \tag{2}$$

IV. RESULTS AND EVALUATION

A. VALIDATION RESULTS - EXPERT OPINION

In the result of NGT process, the total number of votes are aggregated for each concept in the evaluation matrix as shown in the *Total* column of Table 4. A rounded threshold value of 31, which is 70% of the accumulative number of votes (45), was decided with the consensus of domain experts. We compared all the obtained votes of each concept with the threshold value. The concepts whose aggregated vote rank was less than the selected threshold value were removed. As a result of the NGT process, five concepts were removed from the top-level hierarchical concepts of the WCM, which is 14.7% of the top hierarchical concepts. The removed concepts are mentioned in Table 5 with corresponding vote values less than 31. Moreover, we cross-validated the WCM with a statistical method using structured equation modeling (SEM) for further verification by diverse and random communities' members.

B. VALIDATION RESULTS - USER OPINION

The descriptive statistics of users' opinions about the WCM such as mean, standard deviation, skewness, and kurtosis are illustrated in Table 6. The mean values in Table 6 infer that the users have little confidence in the lower mean values

TABLE 4. Evaluation matrix for nominal group technique (NGT).

Wellness Concepts		PI-1	PI-2	PI-3	N-1	N-2	N-3	C-1	C-2	C-3	Total
Physical	Exercise	5	5	4	4	5	4	5	4	4	40
	Nutrition	4	5	4	4	4	4	4	4	4	37
	Prevention	3	5	3	2	4	4	5	4	3	33
Social	Family	4	5	5	5	5	4	4	4	5	41
	Love	4	5	5	5	5	4	4	4	5	41
	Community	4	5	5	5	5	4	4	4	5	41
	Friendship	4	5	5	5	5	4	4	4	5	41
Intellectual	Problem Solving	4	4	4	4	4	3	4	4	4	35
	Creativity	4	4	4	4	4	3	4	4	4	35
Demographics	Gender Identity	5	5	4	5	4	5	5	4	4	41
	Cultural Identity	5	5	4	5	4	5	5	4	4	41
Sense	Sense of Worth	5	5	4	5	4	4	5	4	5	41
	Sense of Control	5	5	4	5	4	4	5	4	5	41
	Sense of Humor	5	5	4	5	4	4	5	4	5	41
Mental/Stress Management		5	5	5	5	5	5	5	4	5	44
Spiritual		4	4	5	3	4	4	4	3	4	35
Emotional		4	4	4	4	5	4	3	4	5	37
Occupation		5	5	5	4	4	5	5	4	5	42
Self-care		3	4	4	4	4	3	4	4	4	34
Leisure		4	5	5	3	4	4	4	4	4	37
Education		5	5	5	4	5	4	5	4	4	41
Thinking		3	3	3	3	3	4	2	3	3	27
Self-worth		4	5	4	5	4	4	4	4	4	38
Media		3	3	2	4	3	2	3	2	3	25
Government		2	3	3	4	3	3	2	3	2	25
Local Safety		5	5	4	4	4	4	4	4	4	38
Institutional Concern		4	4	4	4	3	4	4	4	3	34
Personal Attribution		4	3	3	3	3	3	3	4	3	29
Physiological		4	4	4	4	4	4	5	4	4	37
Political		2	3	1	2	2	2	2	3	1	18
Economic		4	4	5	4	2	3	3	3	3	31
Healthcare		4	4	5	4	4	4	4	4	4	37
Environment		4	4	5	5	4	4	5	4	4	39
Liberty		4	3	5	3	5	3	4	3	3	33

TABLE 5. Removed concepts during NGT process.

Concept	Political	Media	Government	Thinking	Personal Attribution
Votes	18	25	25	27	29

(e.g., less than 3.5). The concepts removed during the NGT process, shown in Table 5, have lower mean values than 3.5, which implies that users have similar opinions as experts concerning these concepts.

The standard deviation values infer that users' opinions have a low dispersive tendency; this shows that most of the users have the same opinion on WCM concepts. The skewness and kurtosis values are acceptable for proving a normal distribution, as most of the values are in an acceptable range (between +2 and −2) [69]. The calculated essential values to perform χ^2 and RMSEA tests, are depicted in Table 7 and we used these to calculate χ^2.

We obtained the χ^2 value (2.01) using Equation 1. This value is acceptable because the recommended range for this statistical test is from a high of 5.0 [70] to a low of 2.0 [71]. The calculated statistical test value is tested against the chi-square distribution with $n - 1 = 34 - 1 = 33$ degrees of freedom. The critical value for the standard significance level $\alpha = 0.05$ is 47.400, which is greater than the calculated test value. Therefore, we do not reject the null hypothesis H_0, which indicates that users' opinions about the WCM are very close to the experts' opinions. This statement is depicted in Figure 8 with respect to the values in the *Expert Opinion* and *User Opinion* columns of Table 7. Therefore, the overlapped and adjacent lines of the experts' and users' opinions in Figure 8 illustrate their closeness and agreement on the WCM concepts with a similar opinion. Furthermore, we calculated the RMSEA based on the obtained essential and chi-square values to evaluate the goodness of fit of the WCM.

TABLE 6. Descriptive statistics of the top-level concepts of WCM.

Wellness Concepts		Mean	Standard Deviation	Skewness	Kurtosis
Physical	Exercise	4.280	0.848	-1.154	0.807
	Nutrition	4.494	0.676	-1.472	2.664
	Prevention	4.239	0.766	-0.979	0.943
Social	Family	4.326	0.775	-1.164	1.212
	Love	4.326	0.775	-1.164	1.212
	Community	4.326	0.775	-1.164	1.212
	Friendship	4.326	0.775	-1.164	1.212
Intellectual	Problem Solving	4.050	0.677	-0.848	1.779
	Creativity	4.050	0.677	-0.848	1.779
Demographics	Gender Identity	3.680	0.941	-0.293	-0.776
	Cultural Identity	3.680	0.941	-0.293	-0.776
Sense	Sense of Worth	4.410	0.616	-0.537	-0.613
	Sense of Control	4.410	0.616	-0.537	-0.613
	Sense of Humor	4.410	0.616	-0.537	-0.613
Mental/Stress Management		4.693	0.475	-1.012	-0.526
Spiritual		3.935	0.896	-0.839	0.865
Emotional		4.267	0.663	-0.809	1.350
Occupation		4.124	0.738	-0.201	-1.143
Self-care		4.304	0.651	-0.810	1.319
Leisure		3.904	0.761	-0.647	0.484
Education		4.354	0.660	-0.793	0.674
Thinking		4.258	0.696	-0.732	0.576
Self-worth		3.994	0.832	-0.544	-0.218
Media		3.404	0.838	-0.204	-0.695
Government		3.062	1.021	0.034	-0.503
Local Safety		4.003	0.653	-0.610	1.253
Institutional Concern		4.102	0.650	-0.103	-0.643
Personal Attribution		3.484	0.840	0.033	-0.571
Physiological		3.634	0.932	-0.487	-0.236
Political		2.829	1.070	0.315	-0.675
Economic		3.885	0.958	-0.602	-0.521
Healthcare		4.174	0.622	-0.137	-0.519
Environment		4.503	0.638	-1.209	1.626
Liberty		4.317	0.748	-0.861	0.196

TABLE 7. Essential values for chi-Square test and RMSEA.

Wellness Concepts		Expert Opinion	User Opinion (O_i)	Expected Value (E_i)	χ^2 value
Physical	Exercise	4.444	4.280	4.514	0.012
	Nutrition	4.111	4.494	4.186	0.023
	Prevention	3.667	4.239	3.733	0.069
Social	Family	4.556	4.326	4.638	0.021
	Love	4.556	4.326	4.638	0.021
	Community	4.556	4.326	4.638	0.021
	Friendship	4.556	4.326	4.638	0.021
Intellectual	Problem Solving	3.889	4.050	3.959	0.002
	Creativity	3.889	4.050	3.959	0.002
Demographics	Gender Identity	4.556	3.680	4.638	0.198
	Cultural Identity	4.556	3.680	4.638	0.198
Sense	Sense of Worth	4.556	4.410	4.638	0.011
	Sense of Control	4.556	4.410	4.638	0.011
	Sense of Humor	4.556	4.410	4.638	0.011
Mental/Stress Management		4.889	4.693	4.978	0.016
Spiritual		3.889	3.935	3.959	0.000
Emotional		4.111	4.267	4.186	0.002
Occupation		4.667	4.124	4.751	0.083
Self-care		3.778	4.304	3.846	0.055
Leisure		4.111	3.904	4.186	0.019
Education		4.556	4.354	4.638	0.017
Thinking		3.000	4.258	3.054	0.474
Self-worth		4.222	3.994	4.299	0.022
Media		2.778	3.404	2.828	0.117
Government		2.778	3.062	2.828	0.019
Local Safety		4.222	4.003	4.299	0.020
Institutional Concern		3.778	4.102	3.846	0.017
Personal Attribution		3.222	3.484	3.281	0.013
Physiological		4.111	3.634	4.186	0.073
Political		2.000	2.829	2.036	0.309
Economic		3.444	3.885	3.507	0.041
Healthcare		4.111	4.174	4.186	0.000
Environment		4.333	4.503	4.412	0.002
Liberty		3.667	4.317	3.733	0.091

In Equation 2, the calculated value of χ^2 is 2.01, df is the degrees of freedom, and N is the sample size. Based on these values, we obtained a value of -0.0029, which is very close to zero. If a value is less than zero under the square root then the RSMEA is reported as zero [72]. Browne and Cudeck stated in [73] that an RMSEA value less than 0.07 indicates a good fit value and a reasonable error of approximation. Similarly, McQuitty mentioned the test of exact fit, which corresponds to the χ^2 test of a model's goodness of fit and requires a confidence interval with a lower bound value of zero for the RMSEA statistic [74]. Therefore, the obtained

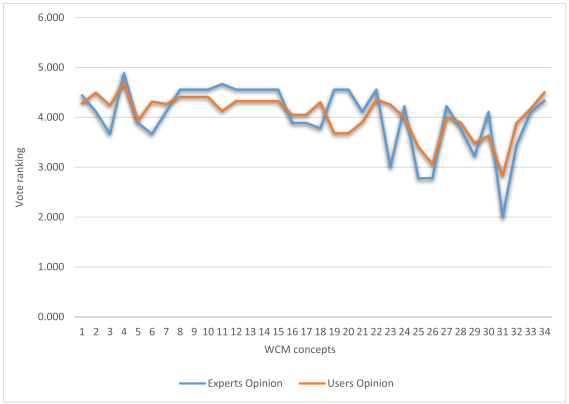

FIGURE 8. Expert and user opinions about WCM.

value of -0.0029 of the RMSEA shows the goodness of fit of the WCM as a well-fit and exact fit model based on the comparison between experts' and users' opinions.

C. WCM EVALUATION

We evaluated our ontology using OntoClean with the help of three experts. The experts were provided with a sample of concepts (62 Concepts out of 442) from the ontology. They were also provided with the definitions of OntoClean meta properties such as rigidity, identity, unity, and dependency. The experts annotated the concepts and we compared the results for finding out the conflicting annotated concepts. The total number of annotations were $c * e * m$, where c is the sample of concepts to be annotated, e is the number of experts who annotated the sample, and m are the meta properties that are used for annotating the concepts. Therefore, the number of annotations were 768. In cases where disagreement existed between experts, we applied majority voting strategy for selection of the meta-property. The meta-properties annotation for WCM is given in Table 8.

Currently, the WCM contains 442 classes, 956 axioms (500 logical and 456 declaration axioms), and 15 properties. The object and data properties are represented as semantic relationships in domain and range triples. For instance, the domain *Person* has property *hasNeed* with ranges *Civil Liberty*, *Political Liberty* and others. Similarly, the domain *Patient* has the property of *SuffersFrom* with range *Disease*. Figure 9 illustrates partial semantic types of different WCM concepts. Figure 10 shows the partial resultant WCM ontology. The WCM is available at the following link of GitHub. https://github.com/taqdirali/Mining-Minds/blob/master/knowledge-curation-layer/i-kat/WellnessConceptsModel.owl

V. DISCUSSION

Standard wellness terminologies help with obtaining interoperability, concepts consistency, and shareability features in documentation, information retrieval and knowledge management. There are a number of reasons for knowledge-based systems limited adaption by different stakeholders.

TABLE 8. OntoClean meta-properties information of WCM.

	Rigidity				Identity				Unity				Dependence		
	+R	-R	∼R	NA	+I	-I	+O	NA	+U	-U	∼U	NA	+D	-D	NA
Expert 1	29	21	12	2	41	2	18	3	36	16	10	2	40	24	0
Expert 2	26	18	20	0	39	5	18	2	33	9	20	2	36	28	0
Expert 3	18	23	10	13	38	1	10	15	25	11	11	17	42	4	18
Total	73	62	42	15	118	8	46	20	94	36	41	21	118	56	18

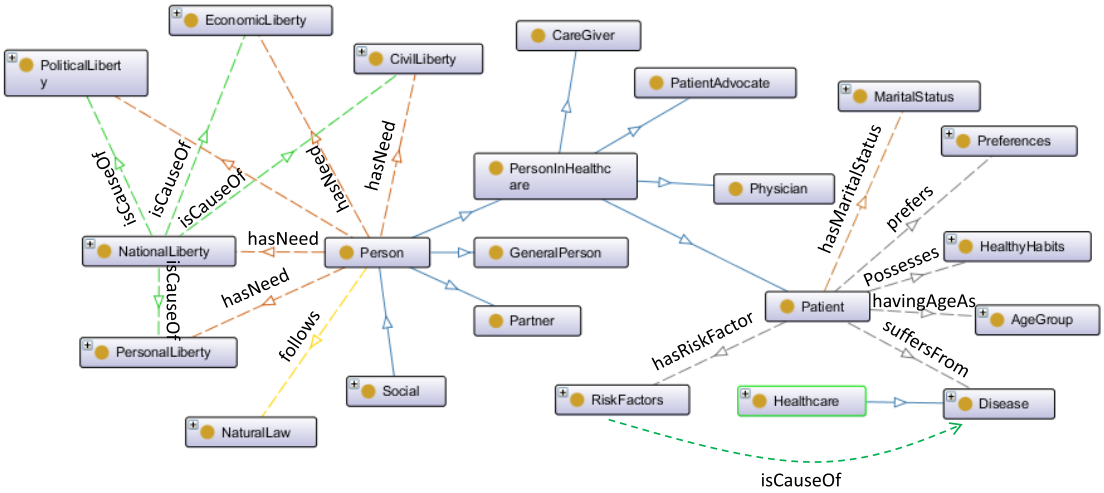

FIGURE 9. The partial semantic types of WCM concepts.

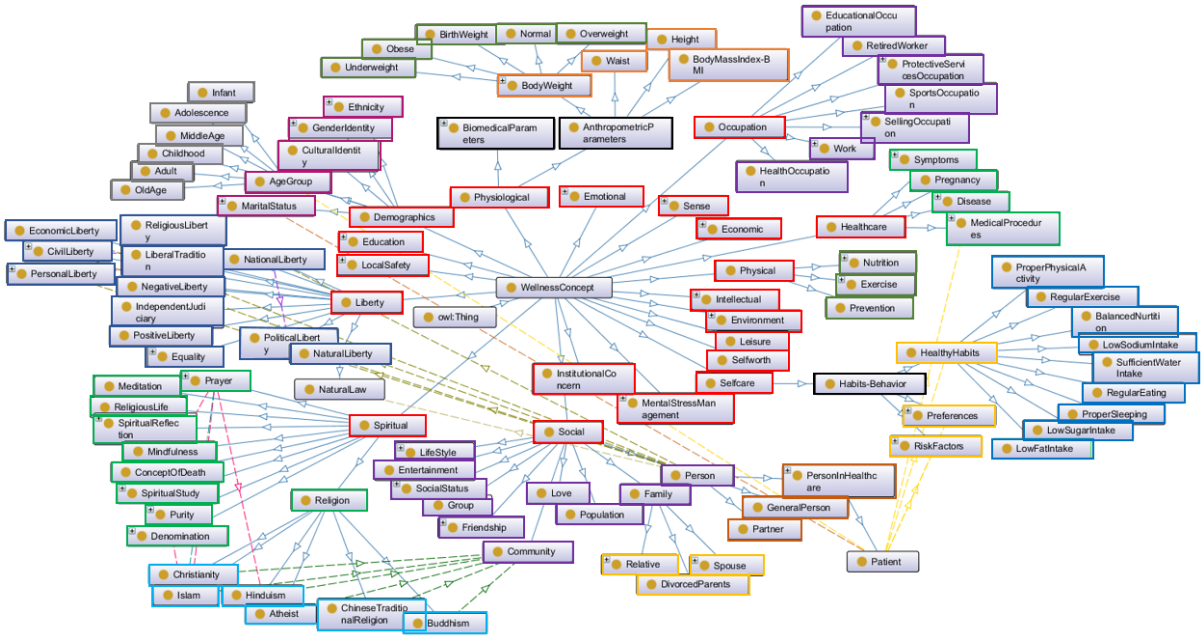

FIGURE 10. The partial resultant ontological representation of WCM.

WCM helps in resolving these limitations. The reasons include;

- The ease with which experts utilize and maintain the knowledge base using controlled vocabulary is an important factor for longer adaption of the system. WCM provides the controlled vocabulary to experts for engineering and evolving the knowledge base by hiding the complexities from him/her.
- An integrated health and wellness system is the vision of the research community. This is only possible if standards are used, resulting in shareable knowledge. Current wellness systems adaption of standards is very

minimal, therefore shareability is an issue. WCM incorporates SNOMED CT terminology standard for resolving the shareability aspect.
- Wellness domain lacks a model that can be utilized for building wellness systems. WCM provides the roof to engineers for utilizing our model to develop wellness systems.

There also exist limitations in the implementation of WCM which is an on-going research area for the expansion of our system. These are described as follows;
- Concepts can be categorized into two types, generalized and localized concepts. Normally, the generalized concepts mapping with the terminology standard (SNOMED CT) can be easily done with sufficient expertise or involvement of matching algorithms. On the other hand, localized concepts are part of WCM but are non-existent in SNOMED CT. Therefore, alignment of WCM localized concepts with SNOMED is our on-going research as it has a direct effect on the shareability aspect.

The existing terminologies and model development methodologies usually focus on some specific elicitation approach according to their requirements. The evolution of the existing terminologies depends on the domain experts' knowledge and heuristics to add new contents. Similarly, they do not consider any standard terminology harmonization and validate the model through domain experts. On the other hand, our proposed methodology evolves the model using published articles and guidelines addition to domain experts' knowledge. We harmonize the model with clinical standard terminology to reuse the standard concepts of SNOMED CT.

We already described in section I-A that wellness is more than healthcare because health is state of physical, mental, and social well-being, while wellness is a state of living an optimal healthy lifestyle [2], [3]. The left side of the continuum in Figure 1, illness - health, is considered as the clinical aspect of the healthcare domain, because clinical aspect mainly focuses on disease, diagnosis, treatment, operations, and medicines [75], [76]. The clinical terminologies concern about the use of concepts in medical record or other clinical information systems [77]. However, clinical terminologies cover most of the clinical concepts and give less coverage to the non-clinical wellness concepts. One way to amalgamate wellness concepts with clinical terminology such as SNOMED CT is making Clinical Observations Recordings and Encoding (CORE) Problem List subset of SNOMED CT. There are well-known methodologies for encoding Problem Lists such as EMR based Problem List for general practice in British Columbia, Canada [78]. Similarly, a methodology for extracting intensive care unit (ICU) problem list have been proposed in the study [79]. The authors focused on the diagnosis concepts for admission to the ICU, anatomical locations and causes of diseases, and different relation types, which are used in Diagnoses for Intensive Care Evaluation (DICE) [79]. A Danish national subset for the nursing problem has developed to intend the standardized homecare nursing documentation for comparable reporting across the 98 Danish municipalities [80], Højen *et al.* included 80 concepts of ''Clinical findings'' into the resultant problem list.

Mostly, the problem lists focused on the clinical aspect of concepts in recommended 4 hierarchies ''Clinical findings, Procedure, Situation with explicit context, and Events'' for building CORE problem lists [81]. As the scope of wellness domain is more than healthcare; therefore, some of the necessary concepts in wellness domain are not part of the SNOMED CT ontology. This restricted us from building SNOMED CT Problem List and compelled us for modeling a standalone WCM ontology. Some examples of concepts in WCM that cannot be enlisted as SNOMED CT Problem List includes Spiritual, Liberty, and Hospitality.

Validation through the NGT method is an appropriate method to validate the holism of WCM hierarchical concepts. However, NGT validation is a very hectic and tedious task for domain experts to validate all the evolved concepts of the WCM in a single session. After evolution, the WCM has thousands of concepts, which cannot be validated by domain experts using a multi-voting process. Therefore, the statistical method of SEM is a suitable approach to validate the evolved WCM based on a large data set that covers all the evolved concepts.

The experts' and users' opinions on the hierarchical concepts of the WCM are very similar. Only one concept, *Thinking*, had conflicted values between the NGT and SEM. This concept had a vote of 27, which is less than the selected threshold value and it was removed during the NGT process. On the other hand, with SEM it has a mean of 4.258, which is greater than the threshold mean (mean = 3.5) and it is an acceptable concept according to users' opinions. In this conflicting situation, we preferred to use the experts' opinions. We discovered that the words *Positive Thinking* were used instead of *Thinking* in the questionnaire, which makes that question biased towards positive thinking.

There are many published guideline resources for physical activities, nutrition, and healthcare that can easily be used in the evolution of the mentioned factors of the WCM. Some factors of the WCM may lack published guidelines. Therefore, some factors of the WCM evolved to a high level of depth and some factors evolved to a very low level of depth.

VI. CONCLUSIONS AND FUTURE WORK

In this study, we designed and developed a wellness concepts model (WCM) based on the proposed WCM development framework. The top level hierarchical concepts model of the WCM is designed using extensive literature with a systematic review process, while we evolved the WCM using the wellness concepts used in published guidelines. We performed the harmonization activity to utilize the existing standard concepts, codes, and descriptions in the WCM. We validated the top level concepts of the WCM using the NGT process and cross-validated them using the statistical methods of structured equation modeling (SEM).

In the future, we will extend this study to validate the evolved WCM with statistical methods on a large data set. We will integrate WCM in knowledge acquisition tool to create interoperable knowledge, and we will integrate it with heterogeneous data model systems to prove the applicability of the WCM with respect to knowledge acquisition.

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